Understanding Oils & Fats and Processing aspects in practice

LOTTE FOODS
Kim Jong Gil
Agenda

1. What is Oils & Fats?
2. Edible Oil Processing
3. *Trans* Fatty Acids
4. Latest Technologies Adopted in Lotte Foods
   - DIC Vacuum Production and Nanoneutralization in Refining Process
   - Environmentally Friendly Energy Saving in Plant Management
What is Oils & Fats?
Definition of Oils & Fats

**:油** (Oil) usually liquid at room temperature
ex) soft oils: soybean oil, rapeseed oil, corn germ oil,…

**:脂** (Fat) usually solid at room temperature
ex) Hard oils: palm oil, coconut oil, lard, tallow,…
Classification of Oils & Fats

Vegetable Oils
- Soybean oil, corn germ oil, rapeseed oil, sesame oil, perilla oil, cottonseed oil, peanut oil, rice bran oil, olive oil, sunflower oil, safflower oil, ...

Vegetable Fats
- Coconut oil, palm oil, palm kernel oil, cacao fat

Marine Oils
- Fish oils

Animal Fats
- Tallow, lard, butter

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Vegetable Oils</th>
<th>Animal Fats</th>
</tr>
</thead>
<tbody>
<tr>
<td>Taste</td>
<td>Fresh, bland, light</td>
<td>Heavy/dense</td>
</tr>
<tr>
<td>Stability</td>
<td>Liquid oils: unstable but convenient</td>
<td>Strong flavors in frying (heating) and good oxidative stability</td>
</tr>
<tr>
<td></td>
<td>Hard oils: still stable in frying (heating)</td>
<td></td>
</tr>
<tr>
<td>Nutrient</td>
<td>No cholesterol and rich in essential fatty acids</td>
<td>High polyunsaturated fatty acid (DHA) and pre-vitamins</td>
</tr>
</tbody>
</table>
Outline of Oils & Fats
Main Areas of Resources

- Soybean
- Rapeseed
- Palm
- Coconut
- Pig (lard)
- Corn
- Sunflower
- Olive
- Fish
- Cow (tallow)
- Soybean
Chemistry of Triacylglycerols (TAG)

Major components: triacylglycerols as an ester derived from glycerol and three fatty acids
Minor components: Phospholipids (PLs)/Sterols/Tocopherols (Tocos)/Pigments/Odorous matters

/Valuable vitamin A, D, E, K and essential fatty acid (vitamin F)
Nutritional Values of Oils & Fats

- Storage form of Energy
- Structural components of bio-membranes (phospholipids and cholesterols)
- Metabolic regulators (steroids hormones and prostaglandins)
- Helps in absorption of fat soluble vitamins (A, D, E and K)
- Improves taste and palatability to food
Functions of Oils and Fats in Foods

1st function – Energy ; Foodstuffs
daily intake, supply & demand, self-sufficiency

2nd function – Organoleptic ; Processed foods
taste, consistency, satiety

3rd function – Healthy Benefits ; Healthy functional foods
essential fatty acids, EPA, DHA, tocopherol, β-carotene
Negative Effects of Oils & Fats

- Overintake of energy
  - adult diseases, overweight, obese, high cholesterol, high blood pressure

- Level of serum cholesterol
  - Low density lipoproteins (LDL)
    - Higher level of LDL increase risk of cardiovascular diseases.
  - High density lipoprotein (HDL)
    - Higher level of HDL reduces risk of cardiovascular diseases.

- Required for healthy food table
Dietary Recommendations

- Reduce fats intake controlled calorie
- Intake of vegetable oils
  PUFA over 10% of total fat intake
- Recommended to intake rich in “oleic acid”
  Monounsaturated fatty acid: 13%-18% of total intake calorie
- Functional oils & fats(omega-3 fatty acids)
  EPA, DHA, ALA
- Avoid to intake Trans-fatty acids
Oils & Fats
Processing Aspects
General Flow of Oils & Fats Processing

Seed → Preparation → Extraction → Refining
- Cleaning / Drying
- Cracking
- Dehulling
- Flaking
- Mechanical Extraction
- Solvent Extraction
- Oil

Edible Oil → Modification
- Neutralising
- Hydrogenation
- Interesterification
- Fractionation
- Degumming
- Bleaching
- Winterising
- Deodorising

Salad / Frying oil → Margarine → Shortening
Objective of refinement

- To remove the objectionable co-constituents in the oils with the least possible damage to neutral oils and minimal loss of desirable constituents
- To improve the oil quality with better taste and color and produce high quality oils

Optimum refinement has realized with highly advanced central control system at Cheonan factory of Lotte Foods.

REFINING PROCESSES

Crude oil → Highly purified refining system → Refined oil

- Free fatty acids
- Moisture
- Off-flavours
- Pigments

Lotte Foods
**Degumming Stage in Refinement**

**Degumming**

### Definition of degumming

Designed to remove the phosphatides and certain ill-defined slimes or mucilaginous/proteineous materials from the oils, which is so called “GUMS”.

### Principle of degumming

Generally, in hydrating the phospholipids and mucilaginous gums in order to reduce their solubility in the oil and hence to facilitate their removal with water/acid by centrifuge.
Neutralization Stage in Refinement

Neutral oil, Free fatty acid, moisture, pigments, off-flavours,…

Neutralization (saponification)

\[ R1\text{-COOH} + \text{NaOH} \rightarrow R1\text{-COONa} + \text{H}_2\text{O} \]
Neutralization Stage in Refinement

Neutralization

Definition of neutralization
- Removal of free fatty acids (FFA) and residual gums

Principle of neutralization
- Removal by a chemical reaction with alkali (caustic soda)
Bleaching Stage in Refinement

1. Neut. oil
2. Heating
3. Adsorption
4. Filtration
5. Bleached Oil

- Citric acid
- BE
- Spent BE

Other elements:
- Bleaching reactor
- Pressure leaf filter
- Bleaching earth
- Spent bleaching earth
- Bleaching reactor
- Pressure leaf filter
- Polishing filters
- Stop oil tank
- Steam
- Economiser
- Final heater
- Cyclone
- Final cooler

LOTTE FOODS
**Definition of bleaching**

Basically, an adsorption process to remove coloring pigments (carotene, chlorophylls) and minor impurities like residual phosphatides, soaps, metals and oxidation products.

**Principle of bleaching**

Adsorption on acid-activated bleaching clays and/or active carbons through several adsorption mechanisms [adsorptive properties, acid properties, catalytic properties and ion change properties].
Hydrogenation Stage in Modification

Bleached oil → Heating → RXN → Filtration → Post Bleaching → Harden Oil

Catalyst → H₂ → Spent catalyst

Hydrogenated oil

Spent catalyst

Post Bleaching

Oil-oil heat exchanger

Measuring tank

Reaction heat recovery

Black filter

Hydrogen dosing

Spent catalyst

to bleaching refining

Heating

Vacuum unit

Steam tank

Filtration

Hydrogenated oil

Drop tank

Reaction heat recovery

HU
**Definition of hydrogenation**
A modification process which harden the physical properties of the oil by altering the unsaturation of the acyl groups in addition of hydrogen with nickel.

**Purpose of hydrogenation**
- to increase the melting point of liquid oils (liquid oils in high melting point ➔ sold fats in low melting point)
- to convert unsaturated fatty acids in unstable into saturated fatty acids in stable for increasing the oxidative stability.
Interesterification Stage in Modification

\[ E \rightleftharpoons E + E + E + E + E + E + E \ldots \]

Diagram showing the process of interesterification, including:
- Catalyst
- Steam
- Dryer-Reactor
- Bleach earth
- Bleacher
- Bleach filter
- Spent bleach earth
- Polish filter
- Interesterified oil
- To refining
**Interesterification (I.E)***

**Definition of I.E**
Alteration of the physical properties of the oils by a random interchange of the fatty acids in between and within the different composing triacylglycerols in addition to metal catalysts (NaOCH₃).

**Purpose of I.E**
- To produce low/zero-trans fats
- To change the overall melting profiles smoothen or the melting point of mixture decreased
- To improve the compatibility of the different triacylglycerols in the solid state
- To improve the plasticity of the resulting solid by changing the (re)crystallization properties
- To combine the properties of mixed oils and fats

---

**Interesterification Stage in Modification**

- Degumming → Neutralization → Bleaching → Deodorization → Hydrogenation (I.E Fractionation)
Deodorization Stage in Refinement

Bleached oil → Pre-heating → Heating → Stripping → Cooling → Filtration → Deodorized oil

STRIPPING STEAM

HP Boiler

Vacuum

Off-flavours

FA

LOTTE FOODS
**Definition of deodorization**
A steam distillation process in which the volatile odoriferous components like aldehydes, ketones, peroxides and residual free fatty acids is stripped out.

**Principle of deodorization**
- Steam entrainment of the odoriferous substances that are more volatile than oil under vacuum at a high temperature.

  ➞ Cheonan factory of Lotte Foods produces high quality oils under high vacuum at lower temperature to avoid formation of process contaminants like trans fatty acids and 3-MCPD.
Processing of Oils & Fats

- A process changing the physical properties of refine oils and/or hydrogenate oils treated through refinement and modification from crushing in order to allow them to fit their specific plasticity, emulsification, oxidative stability and roll-in
- Addition of emulsifier, water, flavors and tocopherols into base-stock to produce margarines, shortenings and whipping creams

Processed Oils & fats
- Margarines
- Shortenings
- Whipping creams

Refined oil, Hydrogenated oil
**Definition**

A solid/fluidable blend treated through emulsification, supercooling and plastication after mixing around 80% vegetable oil or animal fat (soybean oil, coconut oil, palm kernel oil, butter fat), and 20% water with added salt, flavorings, color and other additives.

**Characteristics**
- Tasteful
- Improved flavor
- Mouth-feel
- Adjustable to specific requirement
- Easily to cover the defect of butter

**Categories**
- Multipurposes
- Pastry
- Cream
- Bakery

Lotte Foods
Processing of Oils & Fats

Shortenings

Definition

A solid/fluidable processed oils & fats endowed with emulsification and plasticity through emulsification, supercooling and plastication.

Characteristics

- 100% neutral oil
- High storage stability
- No odor, No flavor, added flavor
- Unique appearance
- And flavor

Categories

- Blending
- Frying
- Cream
- Chocolate (Hard Butter)
Definition
A blend treated through emulsification after mixing water with refined oils and other additives.

Raw material categories
- Butter cream: Milk fat over 30%
- Processed cream: Milk fat over 18%
- Vegetable cream

Application categories
- Whipping cream for decoration
- Coffee creamer to soften the taste of coffee
- Bakery Formulation
TRANS FATTY ACIDS (TFA)
1) Artificial fatty acids uncommon in nature, formed when liquid oil rich in double bonds like soybean oil is converted to hard fat by industrial hydrogenation.

2) Unsaturated fatty acids (i.e. have double bonds) of natural oils & fats generally have \textit{cis} configuration which the carbon chain extends from the same side of the double bond, whereas, in \textit{trans} configuration which the carbon chain extends from opposite sides of the double bond.

3) TFA is formed during partial hydrogenation and deodorization of vegetable oils so the food contained margarines, shortenings and refined oils can not avoid the contamination of TFA.

4) Dairy products like milk, butter, tallow and foods contained them naturally include TFA(5%).
Trans Fatty acids

Chemical structure of fatty acids

Saturated Fat

\[ \text{cis-double Bond (bent)} \]

\[ \text{trans-double Bond (straight)} \]
Where does TFA come from?

- **Biochemical hydrogenation by rumen bacteria**
  - In ruminants, TFAs are formed during microbial biohydration, a process of converting unsaturated fatty acids to more saturated end product by gut microbes (milk, butter, cheese, beef, tallow).
  - The major TFA isomer in ruminal content is trans-11 C18:1 as precursor for synthesis of CLA at the tissue level.

- **Chemical hydrogenation of vegetable oils**
  - unsaturated double bond → saturated single bond
  - *cis* type double bond → *trans* type double bond

- **High temperature treatment**
  - High temperature in deodorization (2~3%)
  - Deep fat frying
Trans Fatty acids

Distribution of TFA in industrially hydrogenated vegetable oil and from ruminant fat
Trans Fatty acids

Graphs showing the percentage of trans fatty acids (trans) in sunflowerseed oil, soyabean oil, rapeseed oil, and palm oil at different temperatures (220 °C, 240 °C, 270 °C) and times (0-5 hours). The shaded areas indicate upper limits of conditions as applied during physical refining.
Trans Fatty acids

Note: Shaded areas indicate upper limits of conditions as applied during physical refining.
Source: Jawad, Kochhar and Hudson, 1983.
Trans Fatty acids

Dietary Routes

● Meat products and dairy products
  - ruminant meats and their dairy products
  - USA, Korea – approx. 20% of total TFA in daily intake

● Foods contained margarines and shortening
  - formulated with hydrogenated oils & fats
  - USA, Korea – approx. 80% of total TFA in daily intake

● Deep fat fried products
  - formed in deodorization at high temperature (260°C)
  - frying oils formulated with hydrogenated fat & oil
**Typical level in Oils & Fats**

<table>
<thead>
<tr>
<th>Products</th>
<th>TFA Level(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shortening</td>
<td>13 ~ 42</td>
</tr>
<tr>
<td>Stick margarine</td>
<td>16 ~ 36</td>
</tr>
<tr>
<td>Tube margarine</td>
<td>8 ~ 20</td>
</tr>
<tr>
<td>Partial hydrogenated oil</td>
<td>25 ~ 40</td>
</tr>
<tr>
<td>Butter</td>
<td>2.6 ~ 3.4</td>
</tr>
<tr>
<td>Animal fats</td>
<td>0.2 ~ 8</td>
</tr>
</tbody>
</table>

**Trans Fatty acids**
Trans Fatty acids

Daily Intake

- **USA**
  - ISEO : 8 g/day
  - USDA : 5.3 g/day
- **Portugal**
  - TNO : 1.3 g/day
- **Iceland**
  - TNO : 6.7 g/day
- **British**
  - British Nutrition Foundation Task Force:
    - 4–6 g/day
- **Korea**
  - 4.0~4.5 g/day(Inje Univ. Song et al.)

※ AVG. 4~8g/day(2~3% of total energy intake)
Trans Fatty acids

Janus-faced TFA

- TFA is chemically unsaturated fatty acid,
  but
- structurally similar to saturated fatty acid in aspect of physical properties, metabolism in the body and risks to health.
Trans Fatty acids

Health Risks

- Overweight/Obesity (논쟁의 여지 있음)
- Raises LDL → tend to raise in risk of heart disease and atherosclerosis
- Intake over 2% → 25% increase in risk of coronary heart disease (CHD)
- Some evidences suggesting increased risk of prostate cancer, breast cancer, type 2 diabetes and liver dysfunction
  - Scientists found 3.5 times increase in breast cancer of women associated with higher TFA intakes
Mitigation of *Trans* Fatty Acids

**Interesterification (I.E)**

- Used to modify the physical properties of fatty matters i.e. melting point, hardness and crystallization with an interchange of fatty acid group to produce a new ester.

- Possible to produce low/zero *trans* fat products by IE.

Randomized configuration of fatty acids
**Mitigation of Trans Fatty Acids**

**Dry Ice Condensing (DIC)**

In principle, low temperature and high vacuum can suppress the formation of TFA during deodorization.

A steam distillation process carried out at high temperature over 250°C to eliminate off-flavors but during this severe heating, variable quantities of TFA are formed.

A system that the volatile components are condensed escaping from deodorizer are momentary condensed and frozen on a surface condenser and it makes the system higher vacuum which can deodorize off-flavors at lower temperature suppressing geometric isomerization of fatty acids.

- enhances oxidative stability.
- improves taste and flavor.
- preserves valuable minor components like tocopherols.
- produces low-trans refined oils.

**Refinement**

Conventional

Ice Condensing

Effect
Mitigation of *Trans* Fatty Acids

**Full hydrogenation**

- A hydrogenation to convert unsaturated fatty acids completely to saturated fatty acid until there are no more double bonds.

- Adding hydrogen atoms to double bonds of unsaturated fatty acids is replaced with saturated fatty acids without double bonds.

⇒ *Less trans*
Latest Technologies of Lotte Foods

toward world class level leading global edible oil industry

● DIC Vacuum Production and Nanoneutralization in Refining Process

● Environmentally Friendly Energy Saving in Plant Management
Dry Ice Condensing (DIC)

Makes Mitigation of TFA and 3-MCPD at High Vacuum and Low Temperature Deodorization “POSSIBLE”
Dry Ice Condensing (DIC) Parameters in deodorization

Distillation

- Fatty acid removal
  - wanted
- Tocopherol removal
  - unwanted
- Odor - Flavor removal
  - wanted

Operating Parameters

- Temperature
- Time
- Stripping steam
- Pressure

Thermal action

- Trans isomerisation
  - unwanted
- Polymerisation
  - unwanted
- Heat bleaching
  - wanted

Deodorizer design

Low pressure by chilled water / Ice condensing

- Continuous/
  - Semicontinuous
- Crossflow(tray)/
  - Countercurrent(pack)
- Shallow bed/
  - Deep bed
- Economizing/Cooling/
  - Heating under vacuum
Dry Ice Condensing (DIC)
Latest vacuum production for deodorization

Deodorization → last but critical stage in refining

Primary function = “deodorisation”
→ removal of taste, odour, unwanted volatile compounds
Min. required conditions to guarantee consistent production of high quality oil
= f(feedstock & pretreatment(chem-phy))
{t:=30–60 min.; T=240–250°C; P=3–4 mbar; Steam=0.6–1.2 %}

Secondary function = “stripping” → Vacuum
→ removal of low volatile materials (mainly FFA)
→ selective removal of minor components (ex. Vitamins)
→ elimination of contaminants (ex. Pesticides)
Dry Ice Condensing (DIC)

Deodorization & Pressure: the lower, the better

**Classical approach:**
- High temperature (240–260°C), short time (30–60 min.)
- Sparge steam (0.6–1.2%), moderate pressure (3–4 mbar)

**New approach:**
- Lower (220–240°C), longer time (60–90 min.)
- Lower sparge steam (0.4–0.8%), lower pressure (0.5–1.5 mbar)

Low vacuum production by ice condensing
**Dry Ice Condensing (DIC)**

**Cooling tower water vacuum system**

- **Cooling tower** → **30°C**

- **Deodor. vapour** (100 kg/h)
  - **1 mbar**

- **Motive steam** (1,200 kg/h)

- **Barometric Condenser**
  - **Effluent** (1,300 kg/h)

- **Suction**
  - **Discharge**
  - **Nozzle**
  - **Suction chamber**
  - **Diffuser**

- **From FA condenser**

- **Sparge steam** (100%)

- **Motive steam** (1200%)

- **Effluent** (1300%)
Dry Ice Condensing (DIC)

**Chilled water barometric condenser vacuum system**

Chilled water → 5°C

1 mbar

Deodo vapour (100 kg/h)

Motive steam (400 kg/h)

> 60% reduction

Effluent (500 kg/h)

Booster

Barometric Condenser
Dry Ice Condensing (DIC)

Ice condensing vacuum system

Ammonia → -28°C

Deodor. Vapour (100 kg/h)

1 mbar

Ice Condenser

“Non” condensables (5 kg/h)

Deodor. Vapour (100 kg/h)

1 mbar

Surface Condenser (30°C)

Surface Booster

Motove steam (65 kg/h)

Effluent (65 kg/h)

Effluent (95 kg/h)

Effluent (70 kg/h)

165 kg/h

>87% reduction

LOTTE FOODS
Dry Ice Condensing(DIC)

Why ice condensing vacuum system?

Objective:
- Preservation of low pressure(<2 mar) in deodorizer
- Overall reduction of effluent & odor emission
- Reduce overall operating cost

How:
- By condensing and freezing sparge steam on cold surfaces
- Noncondensable compounds are brought to atm. Pressure by steam boosters

Technology:
- Horizontal/Vertical surface condensers cooled with liquid NH₃ to very low Temperature (<-26°C)
Preservation of low deodorizing pressure by sublimax system

Dry Ice Condensing (DIC)

Ammonia pumps at 0.7 mbar

Typical streamline of process vapor

To deaeration

‘Surge drum’ with ammonia –31.5°C

Water condensing at 0.9 mbar

Sparging steam
Non-condensables
Fatty acids
From deodoriser
Dry Ice Condensing (DIC)

Flowsheet

Vertical 2 condenser design for all capacities (up to 2,500 tpd)
Dry Ice Condensing (DIC)

Condenser cycle

Switch 1 - 2

Condenser 1

Condenser 2

'B' 'C' 'D' 'E' 'A'

'A' 'B' 'C' 'D' 'E' 'A'

Time

A : Condensation 180 min
B : Defrosting 60 min
C : Cleaning 15 min
D : Gradual cooling 90 min
E : Stand-by 15 min
Dry Ice Condensing (DIC)

Operating cost of dry condensing

1. Ice condensing/Freezing (electricity consumption of compressors)
2. Heating of condensers for cleaning (cost of steam for heating hot water tank)
3. Costs of cooling hot condensers to operating temperature
4. Effluent cost
Dry Ice Condensing (DIC)

Operating cost in comparison

- Operating cost (k$/year)
  - Normal water 30°C: ROI: 1 year
  - Ice water 5°C: ROI: 2.5 years
  - Ice condenser 26°C

eg. 300 kg/hr steam (1,000 tpd deodoriser)

Barometric condenser

Lotte Foods
**Dry Ice Condensing (DIC)**

**New Applications**

1. Further improvements allow future deodorizers to operate at 1 mbar
   
   ![Diagram](image)

   Low temp. stripping of temperature sensitive oils:
   - omega-3 oils: fish oil
   - specialty fats: cocoa butter

2. Low pressure/low temperature deodorization will also have a positive effect on the quality of commodity oils
   
   ![Diagram](image)

   Ex. Palm oil at 230° C instead of current 260° C

3. New technological developments are to be expected soon with ice condensing as a key process in future oil refining industry
Hydrodynamic Cavitation Based Minimum Refining with Less/Zero Chemicals towards Sustainable and Innovative Solution

NANONEUTRALIZATION
Nanoneutralization

Challenges of conventional Degumming and Alkali Neutralization

To be More efficient gums/FFA removal

- using less chemicals
- trend towards more intensive mixing

Static  Dynamic  High shear (single stage)  Ultra high shear (multi-stage)

more intensive mixing requiring higher energy input

How to improve efficiency further?
Nanoneutralization

Principle of Bubbling Cavitation

- A process of bubbling cavitation resulted in very high energy density and in very high temperature and pressure at the surface of the bubbles for a very short time at ambient condition (temperature and pressure).

- It gives us new paradigm in principle to control chemical process intensification.
  - to facilitate high temperature reaction
  - to accelerate reaction rate
  - to increase yield

- The bulk condition in the liquid remains statically at ambient temperature and pressure in macroscopic system. So it does not need to insist a reactor highly resistant to heat, pressure and impact.
Nanoneutralization

Feature of Nanoreactor

- Unique internal geometry
- Generation of very small ‘nano’ bubbles in liquid streams
- Liquids (homogeneous/heterogeneous) are fed to nanoreactor with HP pump
- Mechanical and chemical effects
  - Formation of very fine emulsions
  - Increased surface area
  - Strong shear forces
  - Activation of atoms and molecules
  - Initiation of chemical reaction
  - Breakdown of molecular agglomeration

⇒ Reactor, more than just a good reactor
**Nanoneutralization**

**500 TPD Nanoneutralization of soybean oil Industrial data**

<table>
<thead>
<tr>
<th>Feedstock</th>
<th>Water-degummed soybean oil (120–150 ppm P; 0.45–0.55% FFA)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Nanoneutralization</td>
</tr>
<tr>
<td>Process parameters</td>
<td></td>
</tr>
<tr>
<td>- Phosphoric acid [ppm]</td>
<td>0–100</td>
</tr>
<tr>
<td>- NaOH [% 16.6 °Be]</td>
<td>0.7</td>
</tr>
<tr>
<td>- Pressure [bar]</td>
<td>60</td>
</tr>
<tr>
<td>- Temperature [°C]</td>
<td>75</td>
</tr>
<tr>
<td>Refined Oil Quality</td>
<td></td>
</tr>
<tr>
<td>- P-content [ppm]</td>
<td>1–3</td>
</tr>
<tr>
<td>- Ca &amp; Mg [ppm]</td>
<td>&lt; 1</td>
</tr>
<tr>
<td>- FFA [%]</td>
<td>&lt; 0.3</td>
</tr>
<tr>
<td>- Soaps [ppm]</td>
<td>&lt; 100</td>
</tr>
</tbody>
</table>
Nanoneutralization

Projected economic savings

Feedstock: water-degummed soybean oil at 170 ppm P; 0.45% FFA; Rate 40,000 lbs/hr (400 TPD)

<table>
<thead>
<tr>
<th>Savings</th>
<th>USD/month</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.3% oil yield improvement</td>
<td>31,104</td>
</tr>
<tr>
<td>Silica oil yield</td>
<td>1,866</td>
</tr>
<tr>
<td>Phosphoric acid</td>
<td>13,983</td>
</tr>
<tr>
<td>Sodium hydroxide</td>
<td>4,250</td>
</tr>
<tr>
<td>Silica</td>
<td>10,575</td>
</tr>
<tr>
<td>Electricity</td>
<td>(896)</td>
</tr>
<tr>
<td>TOTAL</td>
<td>61,082</td>
</tr>
</tbody>
</table>
Potential Applications in Edible Oil Processing

- Seed → Preparation
  - Cleaning / Drying
  - Cracking
  - Dehulling
  - Flaking
- Extraction
  - Mechanical Extraction
  - Solvent Extraction
- Oil
  - Meal
  - Degumming
  - Neutralising
  - Bleaching
  - Winterising
  - Deodorising
- Modification
  - Hydrogenation
  - Interesterification
  - Fractionation
- Edible Oil
  - Salad / Frying oil
  - Margarine
  - Shortening
- Nano Reactor®
Environmentally Friendly Energy Savings for Sustainability

1. Recycling of wastewater sludge
2. Steam Compressor
Energy Saving – Recycling of wastewater sludge

Background

- Regulation prohibited to abandon wastewater sludge to the sea (해양환경관리법 제 23조 제1항)
- Financial load resulted from incineration of wastewater sludge

Effect

- Environmentally friendly upgrade of corporate image
  - In-house incineration of wastewater sludge
  - Utilization of wastewater sludge as an energy source
  - Mitigation of CO₂ emission owing to eco-friendly wood pellet
- Saving of incineration costs and reduction of fuel consumption by steam production (USD 500,000/year)
Energy Saving – Steam Compressor

Background
- Higher cost and unstable supply/demand due to peak consumption in summertime (570,000 kw/year)
- Delayed lead time of production due to shortage of air supply resulted from capacity up (Refining capacity: 460 TPD → 560 TPD)

Effect
- Saving of electrical power
- Recovery of waste heat
- Reduction of CO₂ emission
Thank you for your attention!

Any Questions?